Research Department Report

A WIDEBAND ABSORBER FOR TELEVISION STUDIOS

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Summary

The acoustic treatment in BBC television studios has taken various forms to date, all of which have been relatively expensive, some of which provide inadequate absorption.

An investigation has been conducted into the possibilities of producing a new type of wideband absorber which, would be more economic, also taking installation time into account, than earlier designs.

This Report describes the absorption coefficient measurements made on various combinations of materials, from which a wideband sound absorber has been developed.

The absorber works efficiently between 50Hz and 10 kHz, is simple and easy to construct using readily available materials, and is fire resistant. The design lends itself, if necessary, to on-site fine tuning, and savings in the region of 50% can be achieved in terms of cost and space with respect to previous designs.

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1. INTRODUCTION

The acoustic treatment used for most BBC Television Studios has for many years been assembled on-site (prior to the installation of other studio facilities) using a variety of materials. This has been costly, both from the point of view of the labour required for the construction of the treatment, and the downtime of the studio involved. In other BBC Television Studios, BBC modular absorbers have been installed, having been manufactured off-site. These have suffered from high material costs due to their relatively small unit size, as well as requiring lengthy, and hence costly, installation time.

More recently, a combined approach was proposed. This consisted of prefabricated modular acoustic panels suspended over BBC modular absorbers, together with an elaborate supporting structure, and culminated in an overall treatment depth of approximately 400 mm. Had it been implemented, the resulting cost of this treatment would have been excessive.

This highlighted the need for an alternative approach to produce effective wideband sound absorption and hence the request for such an investigation from the BBC Acoustic Specialist.

2. SPECIFICATION FOR A WIDEBAND ABSORBER

Taking on the request of the BBC Acoustic Specialist, from Building Design Services (BDS), for a wideband absorber for television studios, the following parameters were identified and used as a model specification:

- the absorber should be of low cost, both in terms of materials and labour;
- the absorber should provide adequate absorption from 50 Hz to 10 kHz, achieving an absorption coefficient between 0.7 and 1.0 for a treated studio;
- manufacture of the absorbers should be conducted off-site, with subsequent easy installation to minimise studio downtime;
- materials for the absorber should be selected as those being readily available throughout the UK and possessing fire resistant qualities;
- the treatment would be required to have a depth of 150 mm
- to present a reasonably attractive surface finish that would be flat and resilient to both impact and abrasion
- the absorber whould need to be adaptable to surface inconsistencies (for example, service trunking)
- the absorber would need to be maintenance free.

3. EXISTING ABSORBER OPTIONS

3.1 BBC modular absorbers

The BBC-designed A1 and B1 modular absorbers[1] were originally produced for use in television studios. They are robustly constructed wideband absorbers, the A1 providing efficient absorption from 80 Hz upwards and the B1 from 125 Hz.

These absorbers consist of 580 mm square plywood frames with a 6 mm hardboard back, all of which must be fireproofed. The front of the absorber is protected by 12.5 mm or 25 mm square weldmesh over 30 mm thick fabric-covered mineral wool of density 144-176 kg/m^3. For the A1 absorber, the mineral wool treatment is mounted on a 150 mm depth of partitioned air space. For the B1 absorber, there is a 70 mm partitioned air space. These BBC modular absorbers can be manufactured off-site, but their installation is slow because their unit coverage is only 0.36 m^2 — an expensive form of treatment that results in an uneven surface finish, which in many cases is not desirable.

3.2 Acoustic quilt

This is constructed from a number of layers of mineral wool or glass fibre interleaved with chicken wire and totally enclosed in a fabric that is generally woven glass. The quilt provides a low cost acoustic treatment for television studios and large sets, and is suspended from a framework — often constructed from standard scaffolding materials, which is expensive.

This type of treatment requires considerable air space behind the quilt (in the region of 1.5 m) to achieve effective wideband absorption; a distinct disadvantage, as studio space is always at a premium. In addition to

this, the quilt lacks resilience to impact and abrasion as exemplified by its installation at the BBC Elstree studios, where the quilting around the scene-dock doors became severely shredded as a consequence of the regular passage of scenery and equipment. Consequently, the acoustic quilt is normally restricted for use in temporary installations.

3.3 Mineral wool absorbers

Constructed on battens *in situ*, this type of absorber[1] has a 150 mm depth of air space which is partitioned horizontally and vertically with hardboard on a 100 mm pitch. The air space is then covered with a 50 mm thickness of mineral wool of density 140-176 kg/m^3; this, in turn, is covered in fabric and a protective membrane of 12.5 mm or 25 mm square weldmesh. The absorber thus produced provides wideband absorption from 63 Hz upwards. This form of treatment is labour-intensive and takes a long time to install.

3.4 BBC modular absorbers with panel absorbers

A combination of BBC D2 modular absorbers[1] (for low frequency absorption) covered by modular prefabricated panels (for high frequency absorption), and mounted on a structural framework, was suggested. This method of treatment proved costly and presented boundary problems. Laboratory tests showed the low frequency absorption to be inadequate.

4. MECHANISMS OF ABSORPTION

The principle means of sound absorption and their mechanisms can be categorised under three headings:

(i) *Helmholtz absorption*

The Helmholtz absorber[2] is a low frequency sound absorber consisting of a tuned resonant enclosure with a vent or port. The air within this enclosure is compliant and the mass of the air in the port reacts with this compliance to create a resonant mechanism. The resonant frequency of this mechanism can be adjusted by changing the enclosed volume of air or the dimensions of the port. Although this type of absorber works well, and any energy not absorbed is re-radiated in a diffuse manner, the construction and siting of Helmholtz absorbers is critical. They are also quite narrow band so there would be a requirement for several different types.

(ii) *Porous absorption*

The porous absorber[3] is perhaps the most common type, taking on many forms, such as carpets, curtains or indeed any fibrous or cellular material. Consider mineral wool as an example; it is a fibrous material which to an incident sound wave presents a labyrinth of airways bounded by fibres. Attenuation of an impinging sound wave is achieved by viscous losses in the interstices. The further the sound wave penetrates the mineral wool the greater the attenuation. The density of the material plays a significant part in this type of absorber. If it is too light, little energy will be lost; if it is too dense, then the acoustic impedance will be too high and the mismatch reflects the sound wave. Porous absorption in the form of mineral wool has been used successfully in studios for the treatment of mid and high frequencies.

(iii) *Panel absorption*

Traditionally, timber panelling has been used effectively for low frequency absorption. This led to the development of modular low frequency absorbers[1] consisting of an air space totally enclosed by a compliant membrane. The absorber can be tuned by varying the depth of the enclosed air space. This type of panel absorber is most useful in the control of the bass rise which is prominent in many studios.

5. WIDEBAND ABSORBER DEVELOPMENT

Developing a wideband absorber that would be acceptable acoustically, visually, structurally and financially, posed a number of problems. Materials that performed well in one sense were quite often deficient or unable to meet the requirements in other respects. Being faced with these possible conflicting properties meant that many measurements and tests were necessary in order to find the most suitable materials for the development of the wideband absorber.

5.1 Initial measurements

Mineral wool of density 33 kg/m^3, designated RW2 (Rockwool), was measured in the ISO-standard reverberation room at BBC Research & Development Department, Kingswood Warren. Mineral wool was chosen as a starting point on account of its popularity of use in various absorbers to date.

Fig. 1 shows the effect that varying the depth of mineral wool has on the measured absorption coefficient. A number of measurements were also

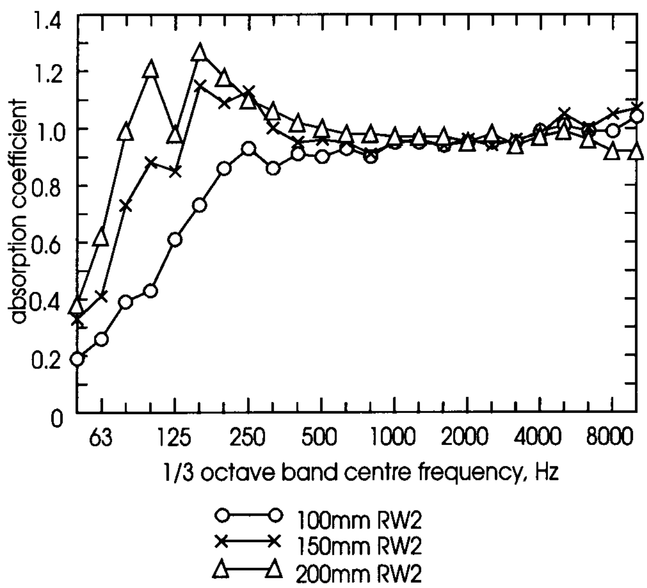

Fig. 1 - The effect of varying the thickness of the Rockwool.

conducted with mineral wool in a chequer pattern, with and without a backing of hardboard, on battens of various sizes, in order to create an air space — all of which produced discouraging results.

From these initial measurements, and from the knowledge of existing acoustic treatment, mineral wool alone would not achieve the desired wideband absorption. Fig. 1 shows that for a 150 mm depth of RW2, the absorption below 100 Hz is inadequate. A combined approach was adopted, using a type of treatment that would consist of high and low frequency absorbent sections. It was reasonable to assume that mineral wool would provide adequate absorption for the mid to high frequencies but the lack of low frequency absorption showed that further investigation was required.

5.2 The superstructure

At this point, it was obvious that consideration should be given to the type of superstructure within which the prospective wideband absorber would be contained. It was necessary to consider the fire resistant aspect and avoid, if at all possible, the use of timber. Much research work has previously been undertaken using metal stud partitions for studio construction[4] and their use in the field is becoming commonplace, so the use of components from these systems appeared to be most suitable.

For the development work, a proprietary metal 146 mm 'C' stud[5] was used, with a 148 mm starter channel[5] at the boundaries, as it was available on-site; although an 'I' stud[6] of similar depth was thought to be a more practical option. Initially, it was proposed to mount the studs horizontally, so that picking up fixing points on a 600 mm pitch from an underlying stud framework of similar pitch would be straightforward. However, after consultation with a BBC structural engineer, the suggestion of placing the studs vertically was adopted. The additional load imposed by the acoustic treatment, whatever its form, would then be carried down through the studs to the floor and not imposed on the wall. Using proprietary studs would also enable them to be fixed in position after the partition/wall had been constructed; thus producing another benefit.

This type of structuring allowed the division of wall space into high and low frequency sections of absorption, with unit widths of 600 mm.

5.3 Low frequency absorption

The decision to treat the low frequency absorption of the wideband absorber as a separate component proved to be the key to the development of the acoustic treatment; but the size and complexity of the BBC-designed D2[1] type low frequency modular absorber were such that adaption of this absorber-type was not possible.

An alternative approach was made by using metal 'C' studs, 146 mm deep, fitted within the ISO-standard test frame on 600 mm centres. Mineral wool (RW2) of 150 mm thickness (achieved by using two layers of RW2, one of 50 mm and one of 100 mm) was packed between the studs and a 3.2 mm hardboard covering screwed into place. The absorption coefficient measurement for this absorber is shown in Fig. 2 *(overleaf)*. The initial slope of absorption has been shifted downwards by one third of an octave to 80 Hz, compared with the result for exposed mineral wool of the same thickness. The hardboard acts as a mask for the mineral wool against significant high frequency absorption, as well as providing a low frequency resonant panel.

With the encouraging results of 150 mm thickness of RW2 in the exposed and covered situations individually, further measurements were made of combinations where one third and one half of the mineral wool was covered with hardboard. Both of these results, seen in Fig. 3 *(overleaf)*, show improved low frequency absorption, with the penalty of reduced absorption at high frequency. However, the effective absorption bandwidth of the combination is increased.

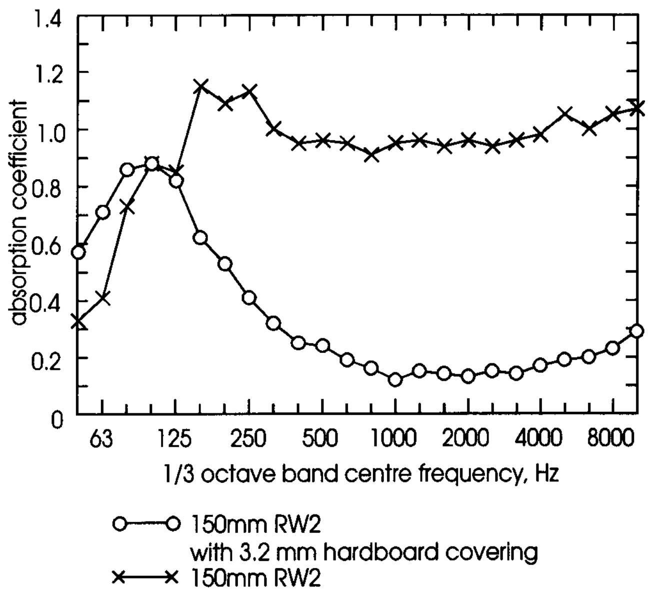

Fig. 2 - The effect of covering 150mm Rockwool with hardboard.

5.4 Materials

Various materials were assessed to identify those most suitable for the wideband absorber in terms of acoustic performance, appearance, mechanical properties, availability and cost.

5.4.1 Glasswool

The use of mineral wool proved to be mechanically unsatisfactory, because even a small amount of handling caused fragmentation of the batts which spoiled their performance. A leading manufacturer [7] of glass-based wool was approached in order to locate a possible alternative to mineral wool. The company manufactured insulation in a wide range of densities and dimensions, available both in batt/slab and roll form. They showed considerable enthusiasm for the project and offered, free of charge, any of their products that would be of benefit.

A fundamental problem still existed; namely, that the insulation was only available in thicknesses up to a maximum of 100 mm, both for mineral wool and glasswool. This meant that more than one layer would be required to achieve the 150 mm depth for the absorber. It was decided to proceed using two layers of glasswool and to readdress the problem of thickness should it be necessary. The nearest equivalent product to RW2 was selected for measurement; this was GB32 in batt form, with a density of 32 kg/m^3. As mass and cost were of importance, GB24 was chosen for comparative purposes. This was the least dense glasswool available in batt form, with a density of 24 kg/m^3 (the insulation in roll format was below this density) and a difference in cost of between 10% and 20% less.

5.4.2 Steel

The hardboard was unsatisfactory because of its tendency to buckle and bulge from variations in temperature and humidity, and the requirement for it to be fire retardant (although it could be treated if absolutely necessary).

Steel appeared to be the only suitable substitute. An equivalent sheet of steel with the same mass would be approximately 0.4 mm thick and would lead to further problems in stability, fixing and damping, in addition to problems of availability. The nearest gauge of steel which was readily available, and relatively inexpensive, was of 0.8 mm (22 swg) thickness. This would be just over twice the mass of the hardboard, but by doubling the mass, the resonant frequency would be shifted downwards one half of an octave [8], which could be used to advantage.

It was decided to opt for Zintec sheet which consisted of 0.8 mm mild steel with a 2.5 micron zinc coating, electrically applied as a protection against corrosion. The choice of Zintec enabled the material to be purchased in a finished and clean condition.

On fixing the Zintec sheet to the metal studs, it was discovered that unless the sheets were fixed perfectly (that is, achieving uniform contact with the studs), unwanted resonances could be induced. For

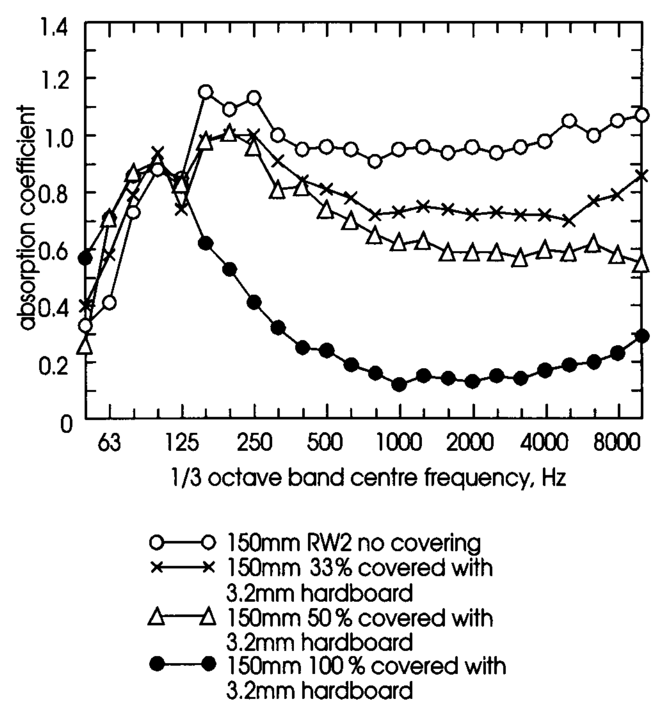

Fig. 3 - The effects of reducing the exposure of Rockwool.

convenience, to counter this possibility, adhesive cloth tape was applied to the face of the studs to act as a gap-filling medium; though in practice, a non hardening mastic could possibly be used with the same effect.

5.4.3 Appearance

The aesthetics of the absorber were considered to be of importance because very large areas of wall space would be treated with it. Options included bonding fabric to or colouring the surface of the absorber, both of which were expensive and would not achieve the desired result without quite seriously affecting the acoustic performance of the absorber.

A material which had already been used in television studio acoustic treatment was woven glass fabric product. The particular fabric that was selected was intended for use as a reinforcing material for industrial conveyor belting. The material is silky in texture and, unlike a woolly fabric, does not accumulate dirt and dust to any significant extent. Subsequent absorption coefficient measurements, using this material as a covering for the steel sheet and exposed glasswool, indicated that, as well as optically masking the substrate effectively, it was almost acoustically transparent in this application.

5.4.4 Protection

Existing methods for protecting acoustic treatment in television studios [1] against impact and abrasion make use of weldmesh in varying sizes; 12.5 mm square for lower studio levels, 25 mm square mid height and 50 mm square mid to full height (where damage is least likely). Weldmesh, 12.5 mm square and 1.2 m in width, was selected for use with the wideband absorber to give the level of protection required. The weldmesh was galvanised, so no further finishing was necessary. Weldmesh in sheet form produced an uneven surface finish and was easily damaged in handling. However, the same material in roll form, although slightly more awkward to handle, produced a visually perfect finish, with the additional advantage of less wastage.

Aluminium strips of 25 mm × 3 mm size, drilled on 600 mm centres for fixing, were used on a pitch of 600 mm to clamp the weldmesh to the underlying studs. Tests with this protective covering showed little if any change in the absorption coefficient.

There was some concern as to how the weldmesh would react at certain frequencies, so listening tests were conducted, together with absorption measurements, and tests which mechanically excited the mesh. From these investigations it was found necessary for the aluminium clamping strips to be fixed on 300 mm centres.

5.5 Further measurements

Absorption coefficient measurements were carried out on separate high and low frequency absorbing structures. The most suitable were then selected to form a combined absorber with a wideband absorption characteristic.

5.5.1 High frequency absorption

Absorption coefficient measurements were made of GB32 and GB24 within the metal stud framework. Fig. 4 shows the comparison and the effect of reducing density by using GB24. Because of these results, and the savings gained in terms of cost and weight, GB24 was selected for the high frequency section of the wideband absorber.

5.5.2 Low frequency absorption

For the low frequency sections of the wideband absorber, measurements were made of 150 mm GB32 and GB24 in the metal stud framework with a total covering of Zintec sheet, compared with a total covering of 3.2 mm hardboard. Fig. 5 *(overleaf)* shows these results. The effect of replacing hardboard with Zintec sheet confirmed the prediction of lowering the resonant frequency by about one half of an octave. Increased absorption at 50 Hz and 63 Hz was also gained by the replacement of the hardboard by the Zintec sheet.

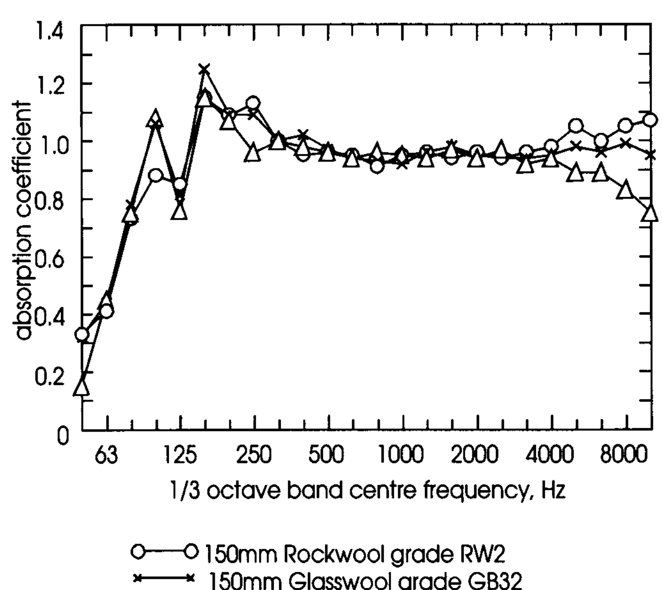

Fig. 4 - Comparative performance of different grades of mineral wool.

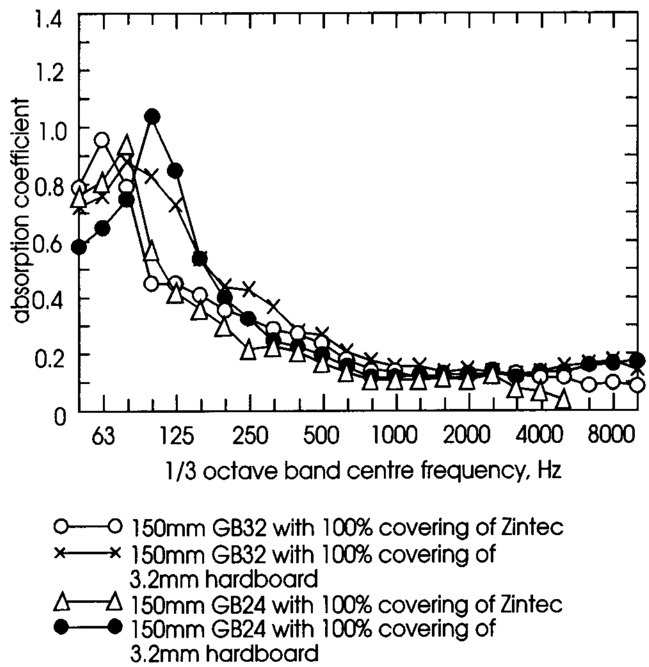

Fig. 5 - The effect of increasing the mass of the covering material.

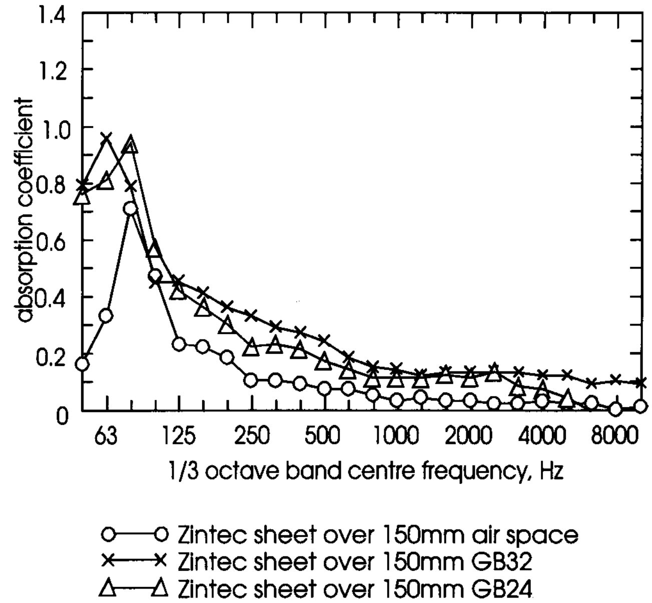

Fig. 6 - Improving the low frequency absorption by treating the air space behind the Zintec sheet.

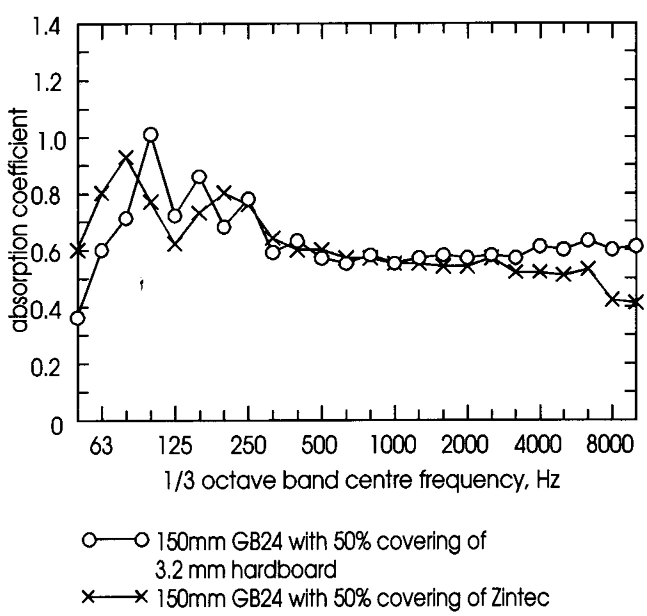

Fig. 7 - The performance of GB24 with different coverings.

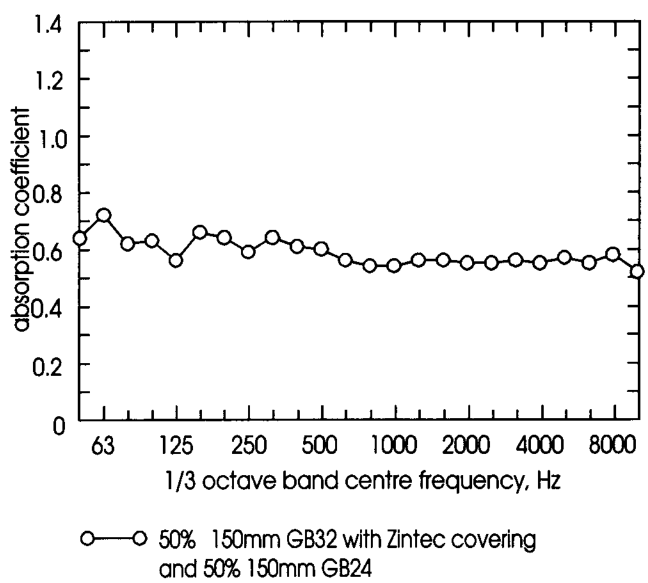

Fig. 8 - A wideband absorber.

Fig. 6 displays the result of fitting Zintec over the metal studs without glasswool present. The inclusion of GB24 or GB32 quite clearly improves the absorption by damping the enclosed air space [9]. The measurement for GB32 with Zintec sheet shows improved low frequency absorption, which can be attributed to the glasswool coupling with the Zintec so damping its motion. For the low frequency component of the finished absorber, GB32 with a Zintec covering was selected for further measurement, in conjunction with the high frequency component GB24.

5.5.3 Discussion of the choice of GB24

Measurements were made using 150 mm depth of GB24, half of which was covered with either hardboard or Zintec. The results are shown in Fig. 7. Although the result using Zintec shows extended bass absorption, there is a significant deficiency at 125 Hz.

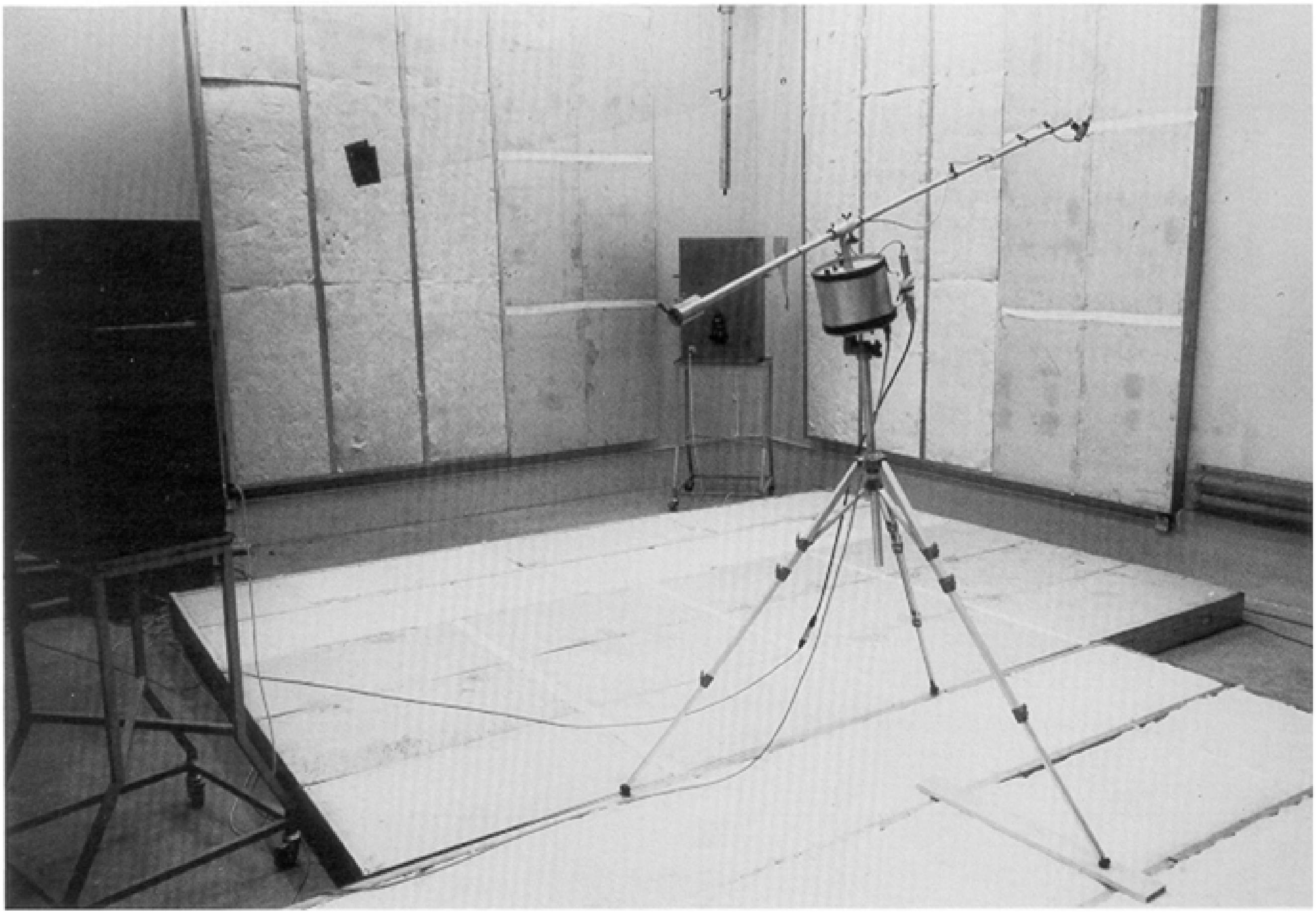

Fig. 9 - 63m² of wideband absorber in the Reverberation Room at Kingswood Warren

Note: *This test installation did not include the finishing surfaces of fabric and weldmesh.*

The hardboard version confirms the poor performance at low frequencies.

These results were not acceptable, so the GB24 under the Zintec was replaced by GB32 and the measurement repeated. The resulting absorption coefficient (Fig. 8) was most satisfactory, showing a uniform absorption characteristic over the whole frequency range. It shows a slight rise in absorption at lower frequencies but this could assist in controlling the bass rise evident in many television studios.

6. LARGE SCALE TRIALS

Sufficient evidence from ISO-Standard measurements now existed to proceed with the treatment of an area with similar dimensions to a typical television studio. The knowledge that absorbers can have very a different effective absorption in a working studio environment to that measured in a reverberation room was good reason to justify the measurement.

The ISO-Standard reverberation room at Kingswood Warren has a volume of 201 m^3. It contained no absorption, and if treated with 63 m^2 of the wideband absorber, would simulate a scaled down version of a heavily treated television studio. The absorber was constructed in four patches, three of 12.6 m^2 mounted on different wall surfaces and one of 25.2 m^2 on the floor (Fig. 9). Fig. 10 *(overleaf)* shows the resulting absorption coefficient compared to an ISO-Standard measurement of a 10.8 m^2 sample of the same absorber. There is a significant increase in the bass absorption but very little difference above 2 kHz compared with the smaller sample. Also shown, is the result of adjusting the ratio of high to low absorber sections by approximately ten percent, giving an overall improvement in the level of absorption at all frequencies down to 63 Hz.

7. FINAL CONFIGURATION

Until now, all the test samples had comprised exposed or covered mineral wool without the addition of fabric or weldmesh. But there was still the problem

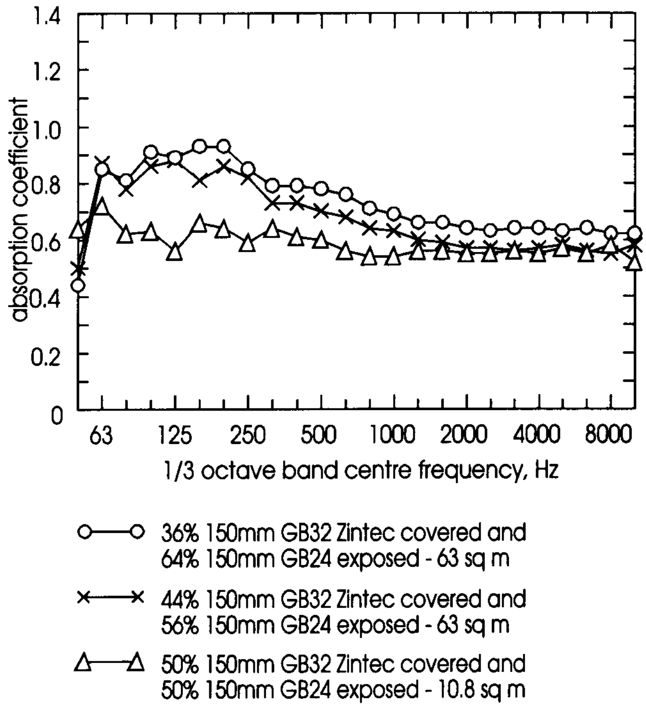

Fig. 10 - Heavily treated combinations compared to an ISO measurement.

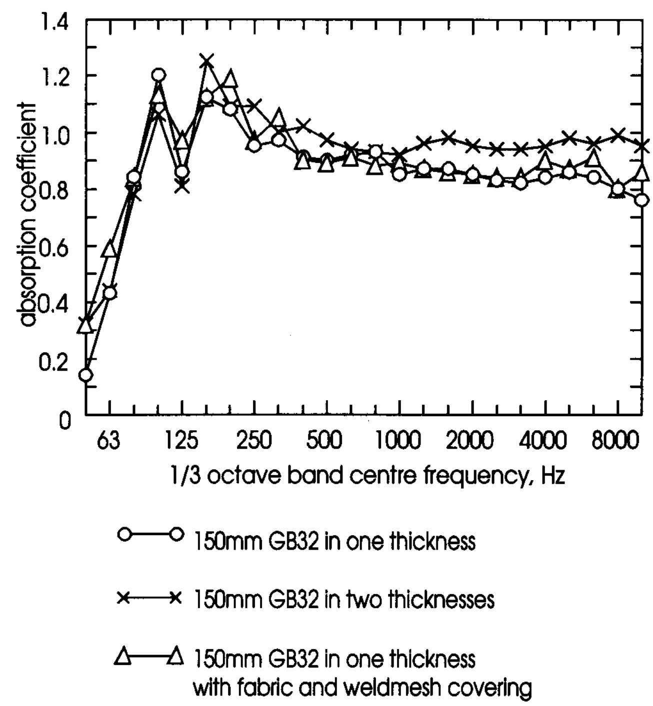

Fig. 11 - The effect of only one thickness of GB32 compared with two.

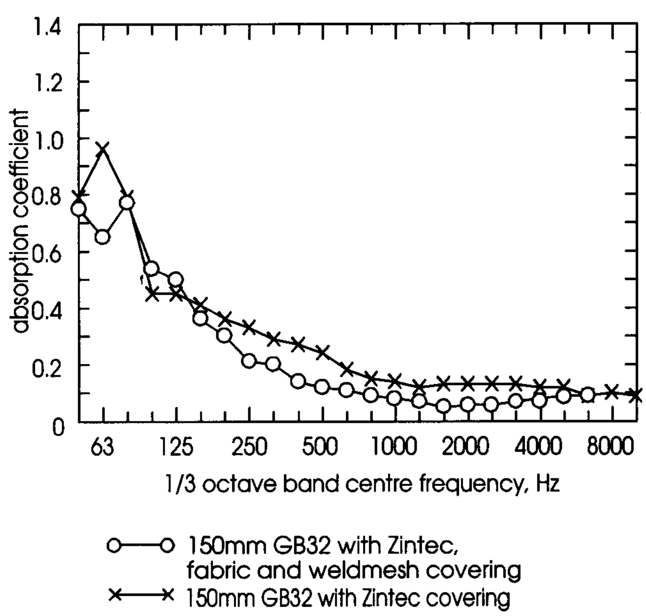

Fig. 12 - The effect of fabric and weldmesh over Zintec covered GB32.

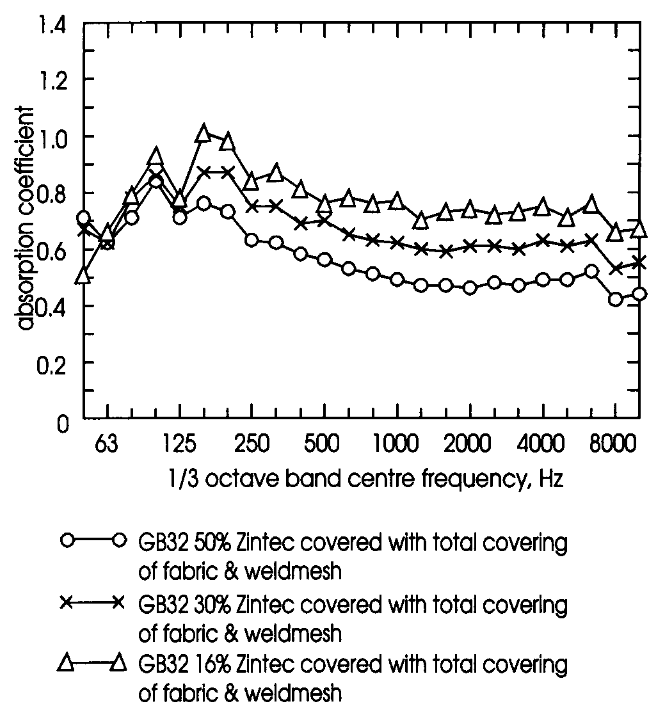

Fig. 13 - Effects of varying the ratios of Zintec to exposed Glasswool.

of glasswool not being available in 150 mm thickness. Consultation with the manufacturer's chemist resulted in their enthusiastic involvement and within a fortnight they had proved it was possible to produce 150 mm GB32 batts and, with slight adjustment, could produce these batts to the same specification as other batts of lesser thickness in the range.

A sample was obtained which was sufficient in quantity to carry out ISO-Standard measurements with

and without a fabric and weldmesh covering. Fig. 11 indicates the performance of the 150 mm GB32 compared to that of two layers of GB32, one 50 mm and one 100 mm. Also shown, is 150 mm GB32 with a covering of woven glass fabric and 12.5 mm square weldmesh (held in position by aluminium strips fixed to the underlying studs). The absorption of GB32 glasswool is not compromised by the addition of the fabric and weldmesh. Similarly, 150 mm GB32 covered with Zintec, fabric and weldmesh was measured and compared with the combination of 50 mm and 100 mm GB32 covered with Zintec. This result, shown in Fig. 12, was less encouraging, as the peak absorption between 50 Hz and 100 Hz has been reduced, together with an almost uniform reduction at higher frequencies. Finally, the combination of the two components for the wideband absorber were measured, using differing ratios of Zintec-to-exposed glasswool. These absorption coefficients are shown in Fig. 13. The 50% and 30% Zintec combinations display effective wideband absorption. The 30% Zintec example maintains the low frequency absorption achieved with 50% Zintec but shows an improved high frequency absorption. The 16% Zintec example, although having a roll-off at the lowest frequency, maintains good high frequency absorption.

Further to these measurements, the absorption coefficients for 30% and 50% Zintec combinations were used as a substitute treatment for an existing studio in a computer room design program. The resulting reverberation time characteristics were within the design limits and flatter than would normally be expected.

In its final form, the wideband treatment has an overall depth of 150 mm; improved low frequency absorption being achieved by using GB32 throughout, with the penalty of increased mass.

8. COSTS

The primary objective of this work was to produce acoustic treatment that would be cheaper than existing forms.

Using GB32 throughout has enabled a reduction in overall cost for a studio acoustic treatment project, compared with the initial proposal for using GB24 in a combination of different densities and thicknesses.

Quantity Surveyors' figures show that the wideband treatment that has been developed is 53-58% cheaper than the various forms of treatment that have been used to date. These figures account not only for material costs but installation costs, together with an allowance calculated on the basis of previous experiences for problem areas.

9. CONCLUSIONS

After a thorough measurement and selection procedure, a wideband absorber system has been produced which comfortably meets all the criteria laid down in the Specifications given in Section 2 of this Report. Fig. 14 shows the construction of the absorber. The performance can be tailored to suit the acoustic environment for which it is intended by adjusting the ratios of Zintec-covered-area to exposed-glasswool-area of the absorber.

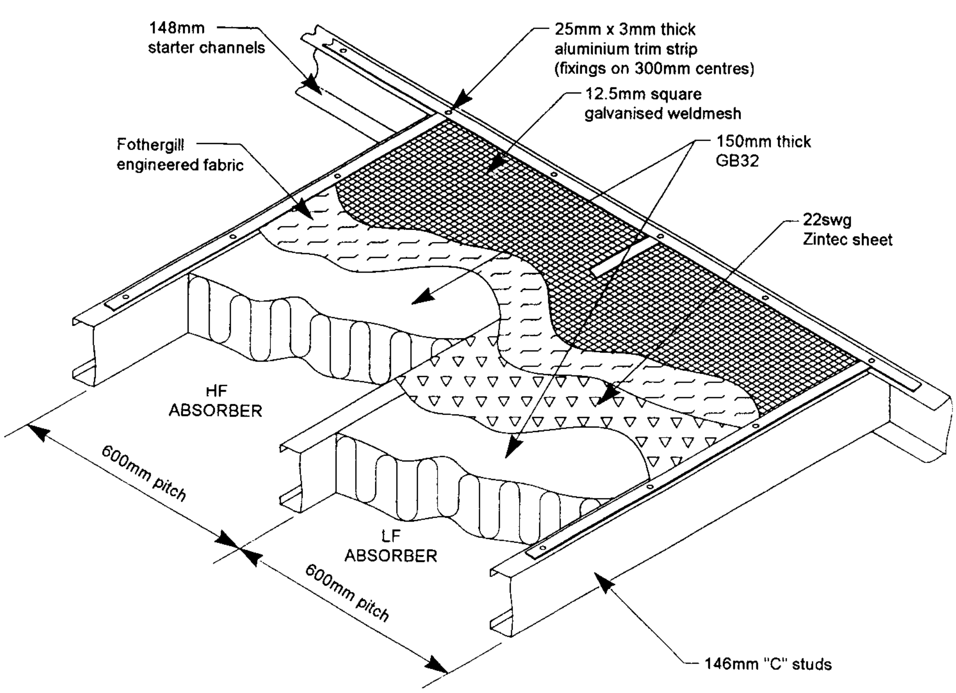

Fig. 14 - The Wideband Absorber

The wideband absorber is simple in structure, all components being manufactured off-site and no further finishing is required after assembly. Large areas can be treated quickly and effectively, with surface inconsistencies being accommodated either by burying them within the absorber or by the fitting of the absorber around them.

The wideband absorber has a functional engineered appearance and by virtue of its material composition is entirely non-combustible.

It should be noted that the wideband treatment in its final form displays greater absorption at low frequencies. This feature can be used to advantage to control the bass rise which is evident in many television studios.

Savings in the region of 50% in terms of material and installation costs, and space-saving (brought about by the reduced thickness of the new absorber) can be realised with the wideband absorber when compared with the cost and dimensions of existing forms of treatment.

The decision to use 150 mm GB32 throughout means that only one material is required, giving savings because of increased quantities and, hence reduced supply costs. The ability to adjust the performance of the treatment before the fabric and weldmesh are fitted is also improved by the use of only one density of glasswool.

10. ACKNOWLEDGEMENT

The author would like to record his appreciation for the enthusiastic help that was given by the late John House, who was technical adviser for Gyproc Insulation Ltd., the manufacturer of GB24 and GB32 (the material eventually used). This assistance, given free of charge by the manufacturers, with minimum delays, has been an important factor in effecting the successful conclusion of this project.

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